



US010736694B2

(12) **United States Patent**
Prakash et al.

(10) **Patent No.:** **US 10,736,694 B2**
(45) **Date of Patent:** ***Aug. 11, 2020**

(54) **ELECTROSURGICAL DEVICES WITH DIRECTIONAL RADIATION PATTERN**

(71) Applicant: **COVIDIEN LP**, Mansfield, MA (US)

(72) Inventors: **Mani N. Prakash**, Boulder, CO (US);
Francesca Rossetto, Longmont, CO (US); **Joseph D. Brannan**, Lyons, CO (US)

(73) Assignee: **COVIDIEN LP**, Mansfield, MA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 848 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **15/382,954**

(22) Filed: **Dec. 19, 2016**

(65) **Prior Publication Data**

US 2017/0100193 A1 Apr. 13, 2017

Related U.S. Application Data

(60) Continuation of application No. 14/242,048, filed on Apr. 1, 2014, now Pat. No. 9,526,575, which is a (Continued)

(51) **Int. Cl.**

A61B 18/18 (2006.01)

A61B 18/14 (2006.01)

A61B 18/00 (2006.01)

(52) **U.S. Cl.**

CPC **A61B 18/1815** (2013.01); **A61B 18/1492** (2013.01); **A61B 18/18** (2013.01); (Continued)

(58) **Field of Classification Search**

CPC A61B 2018/1869; A61B 2018/183; A61B 2018/1853; A61B 2018/1861; A61B 18/1815

See application file for complete search history.

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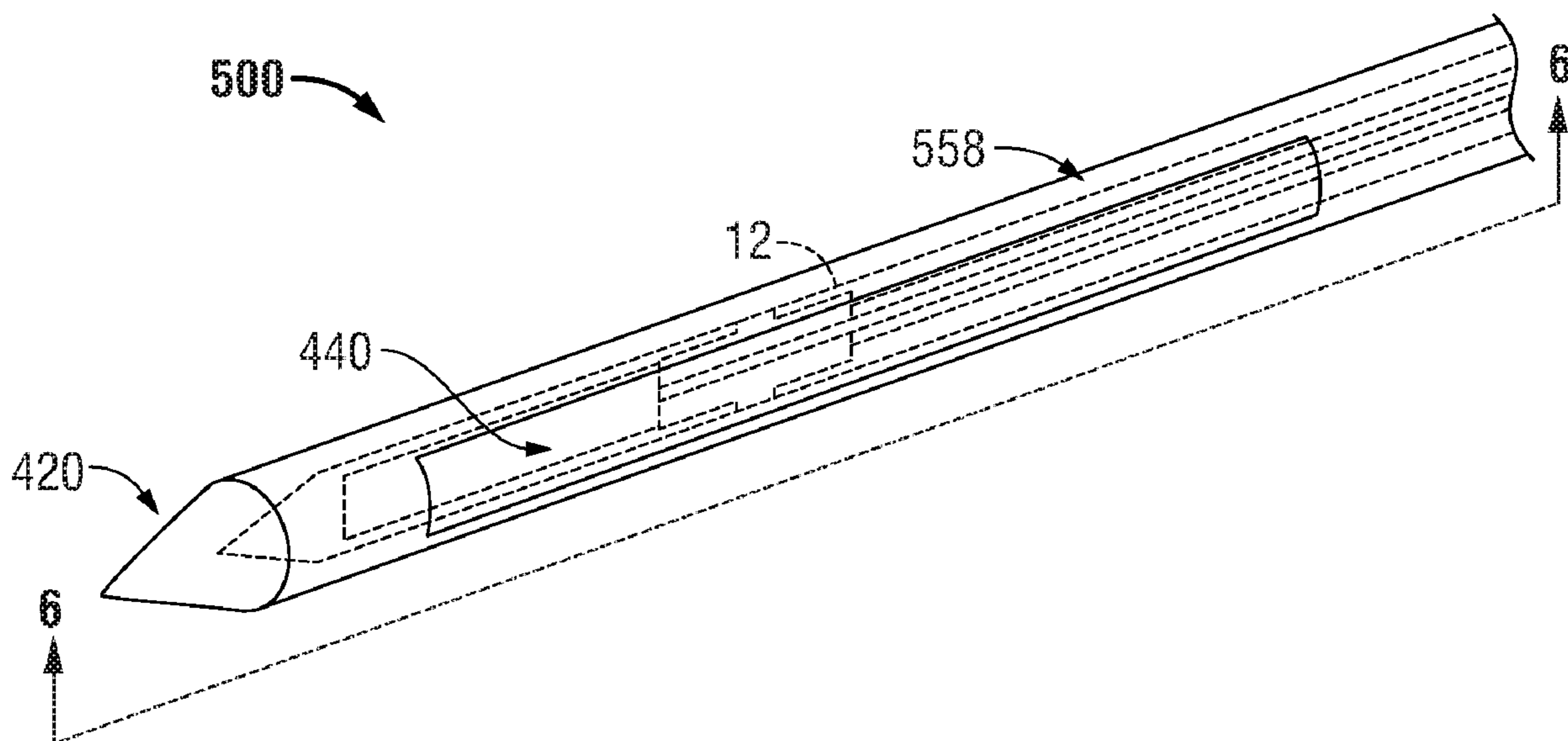
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Primary Examiner — Jaymi E Della

(57) **ABSTRACT**

A device for directing energy to a target volume of tissue includes an antenna assembly and an elongated body member. The elongated body member includes a proximal end portion and a distal end portion, wherein the proximal and distal end portions define a longitudinal axis. The elongated body member has a chamber defined therein that extends along the longitudinal axis, and a body wall surrounding the chamber. An antenna assembly is disposed in the chamber. The elongated body member also includes an opening in the body wall to allow energy radiated from the antenna assembly to transfer into the target volume of tissue.

10 Claims, 6 Drawing Sheets



Related U.S. Application Data

division of application No. 13/567,624, filed on Aug. 6, 2012, now Pat. No. 8,690,869, which is a continuation of application No. 12/476,960, filed on Jun. 2, 2009, now Pat. No. 8,235,981.

(52) **U.S. Cl.**

CPC *A61B 2018/00023* (2013.01); *A61B 2018/00077* (2013.01); *A61B 2018/00083* (2013.01); *A61B 2018/00351* (2013.01); *A61B 2018/00577* (2013.01); *A61B 2018/00589* (2013.01); *A61B 2018/00601* (2013.01); *A61B 2018/1861* (2013.01)

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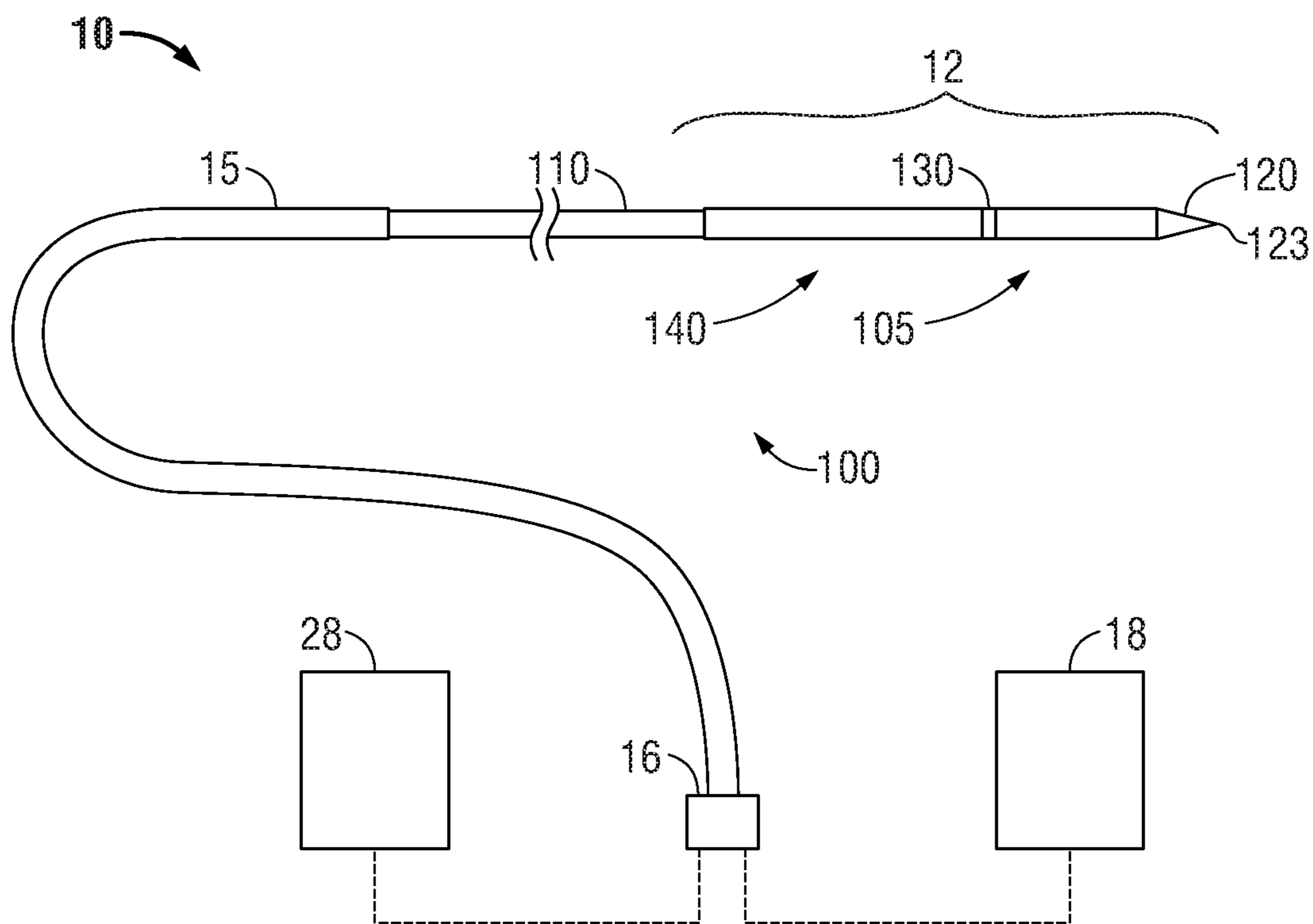


FIG. 1

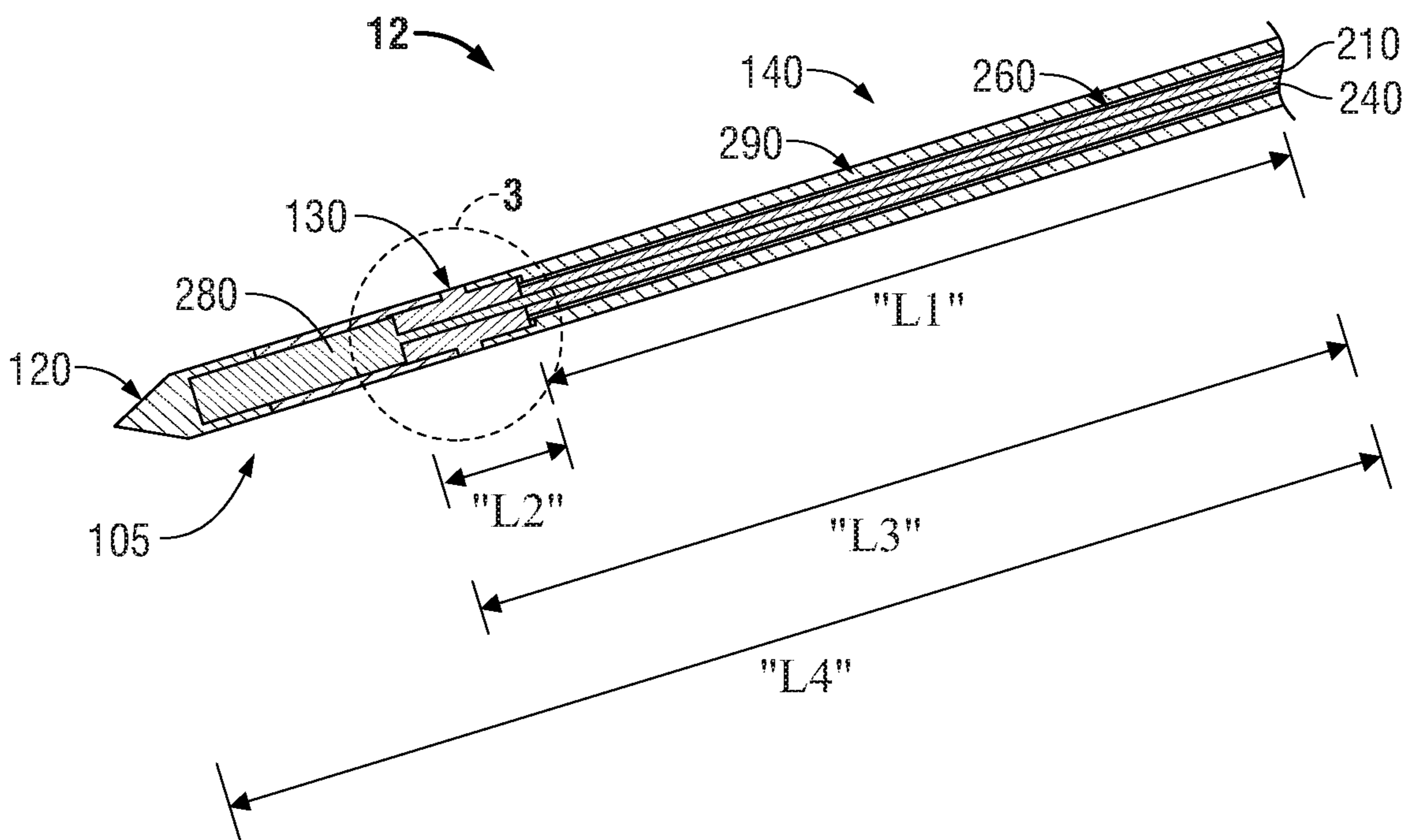


FIG. 2

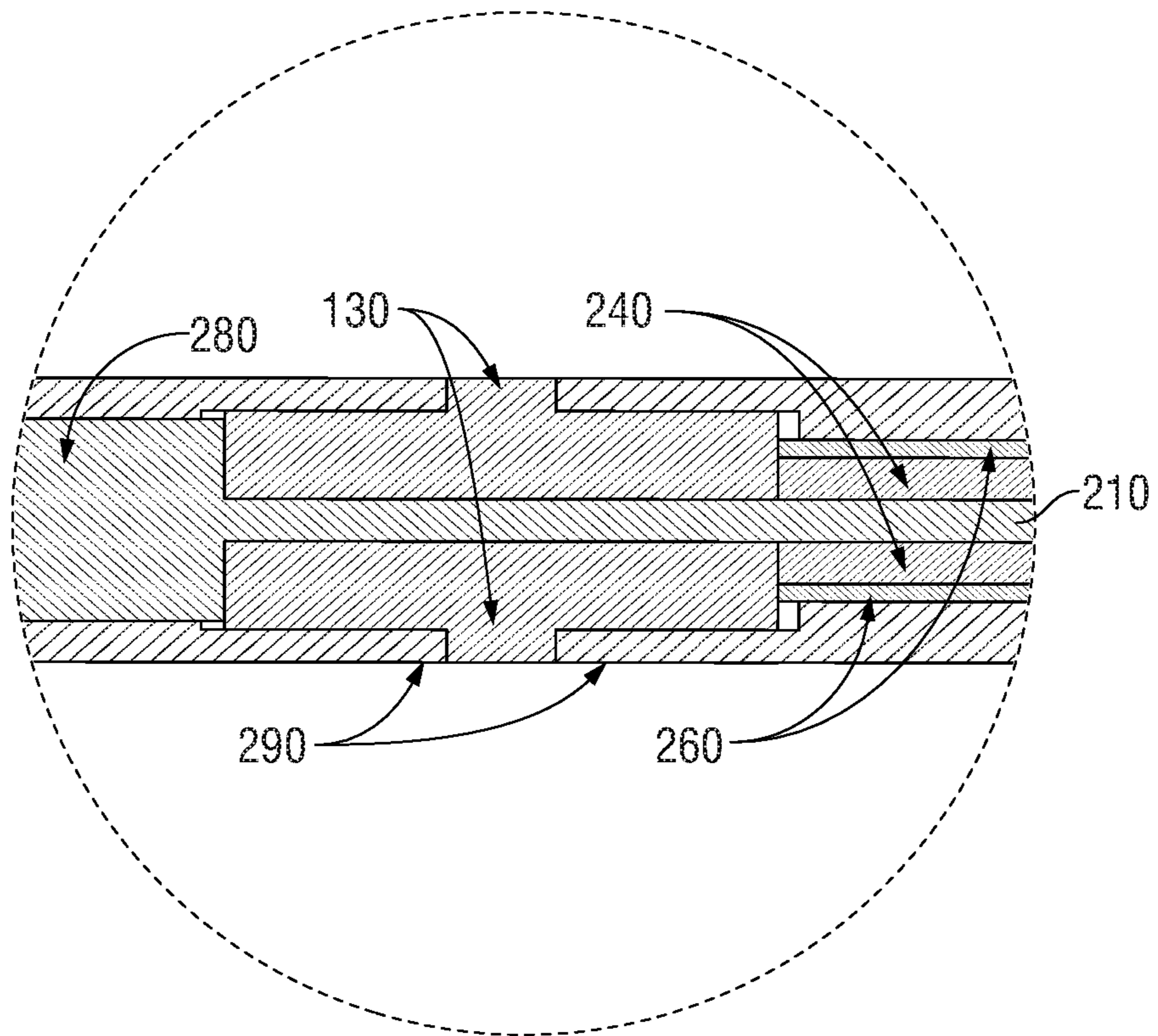


FIG. 3

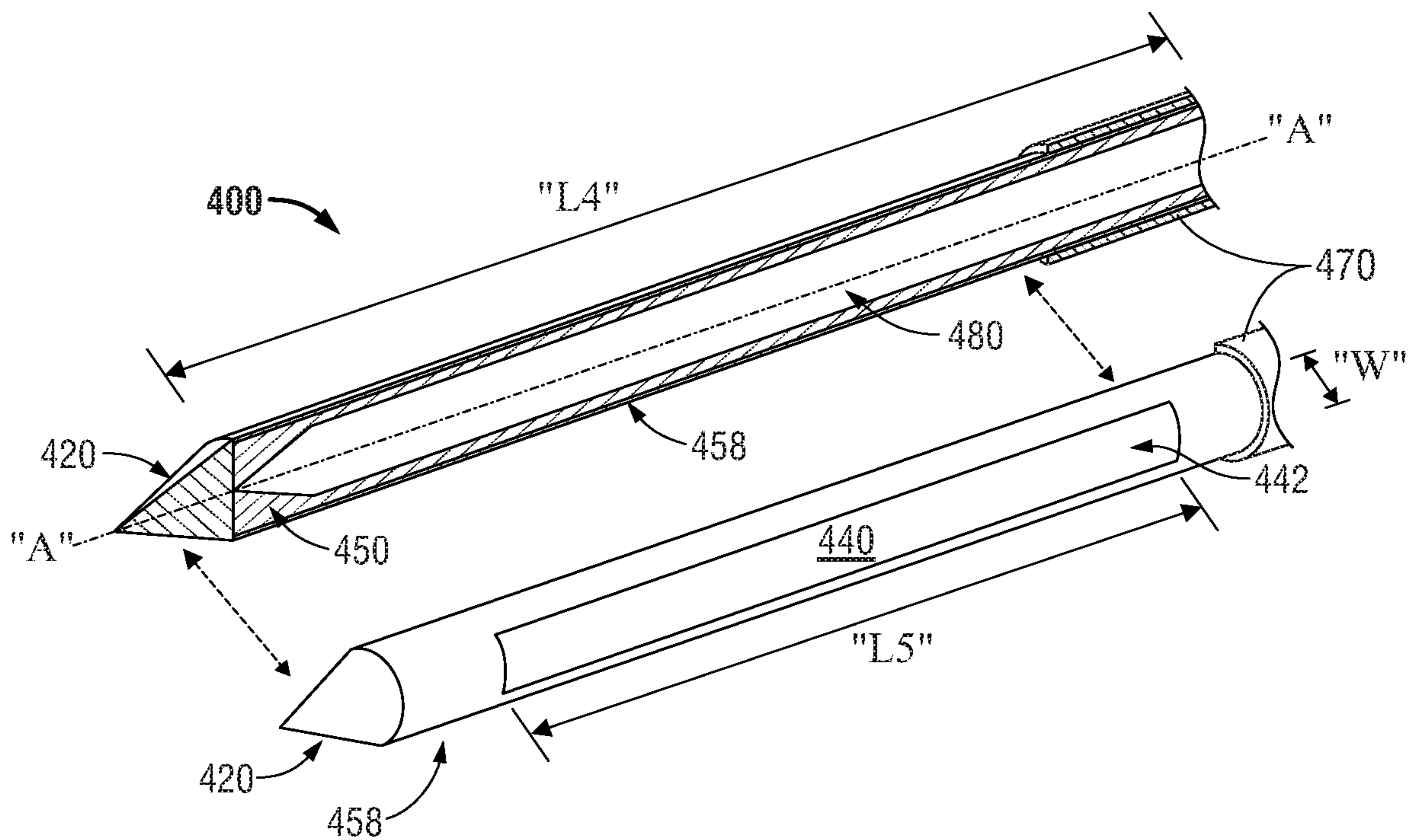


FIG. 4

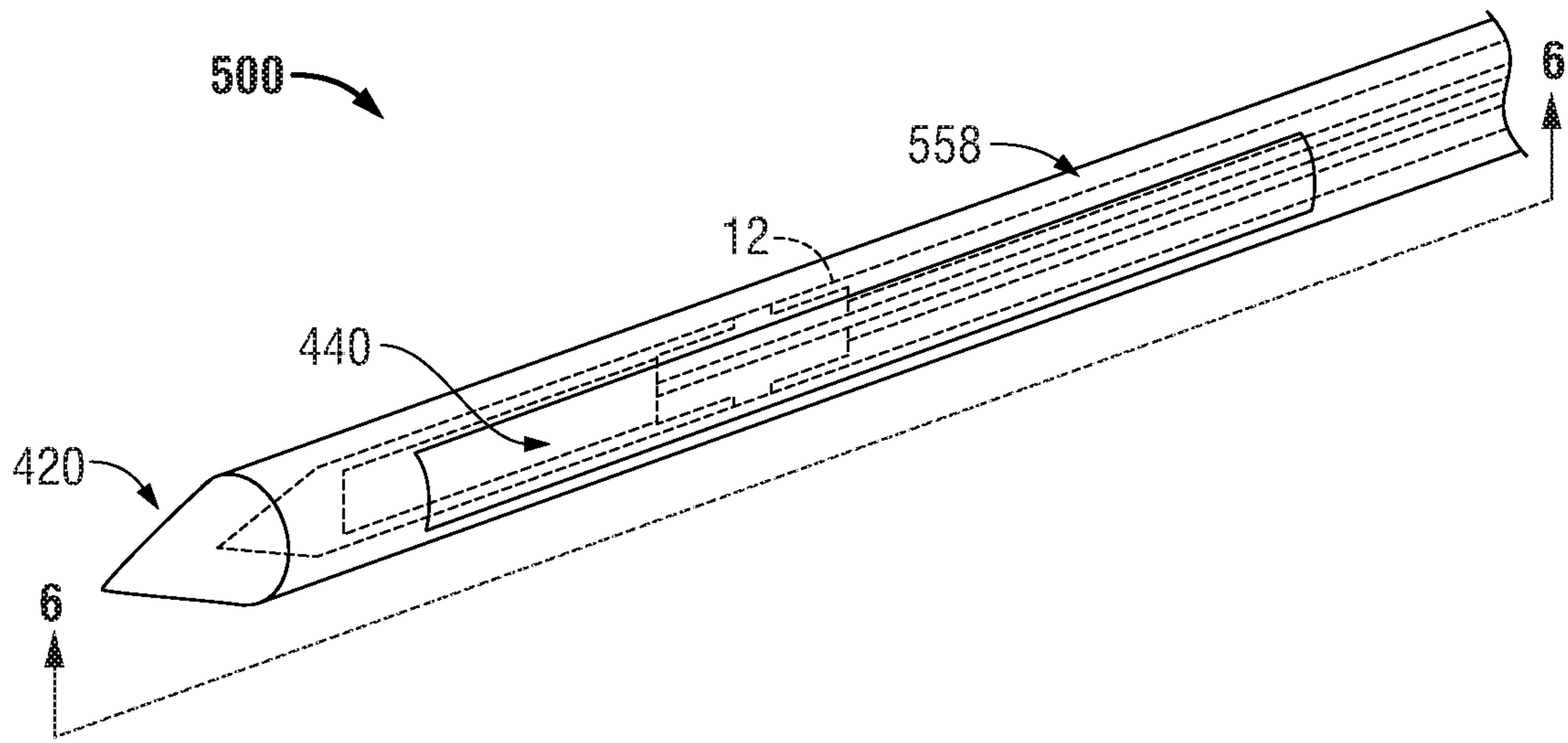


FIG. 5

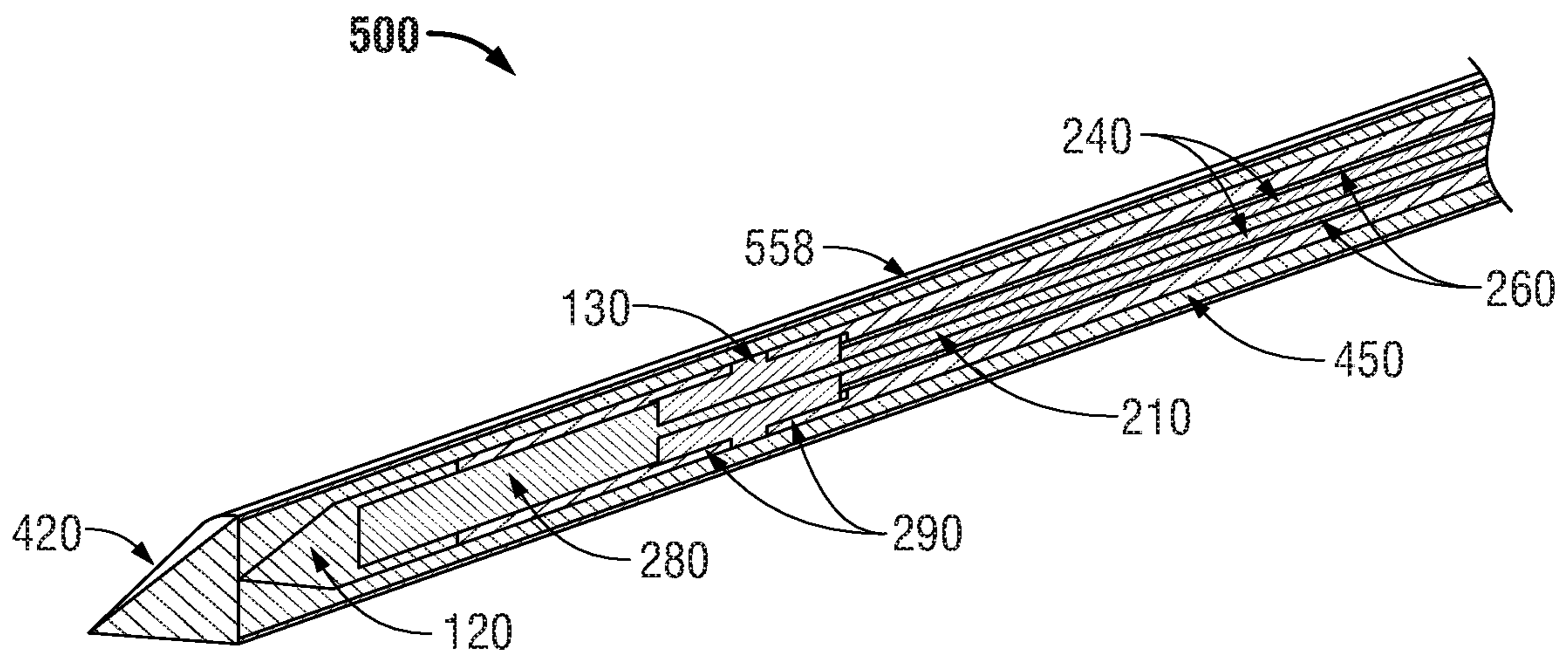


FIG. 6

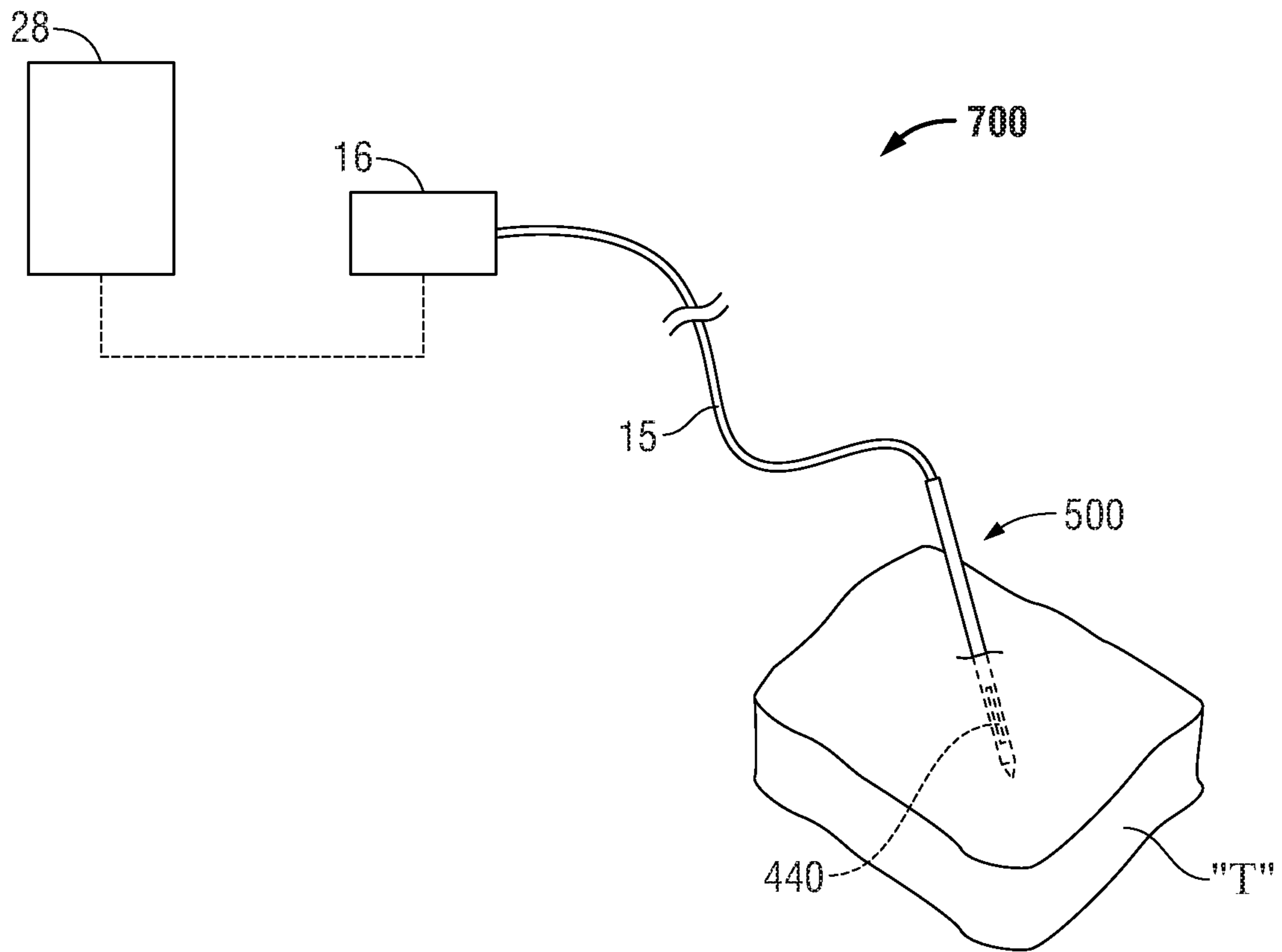


FIG. 7

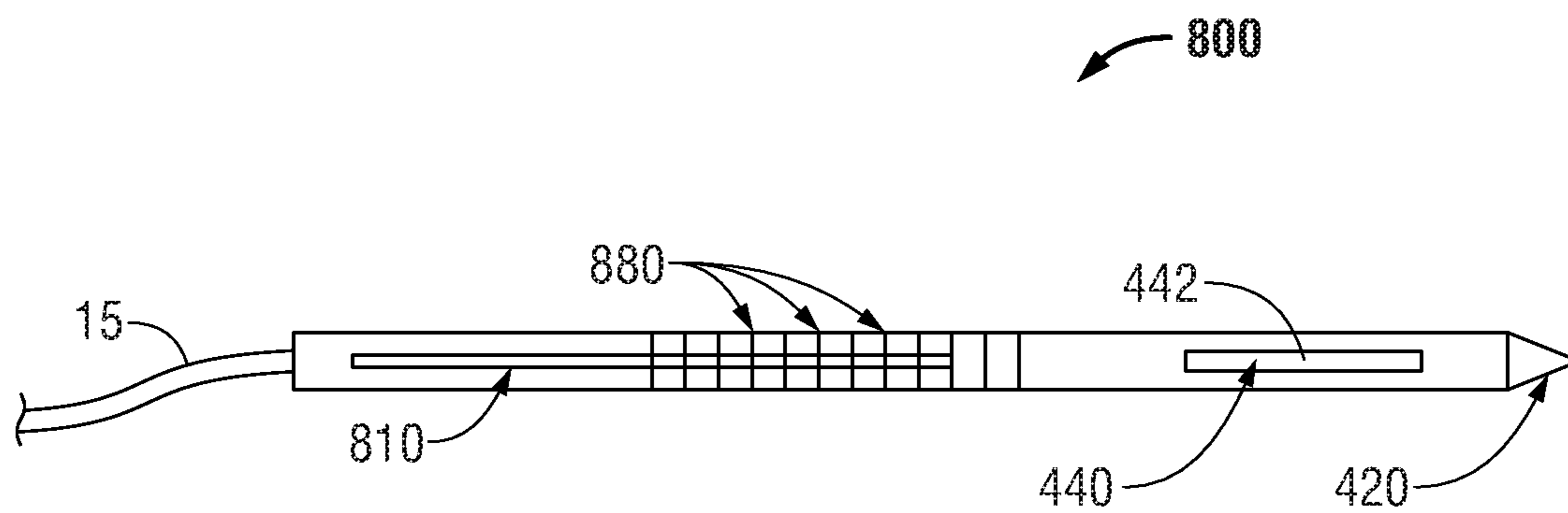


FIG. 8

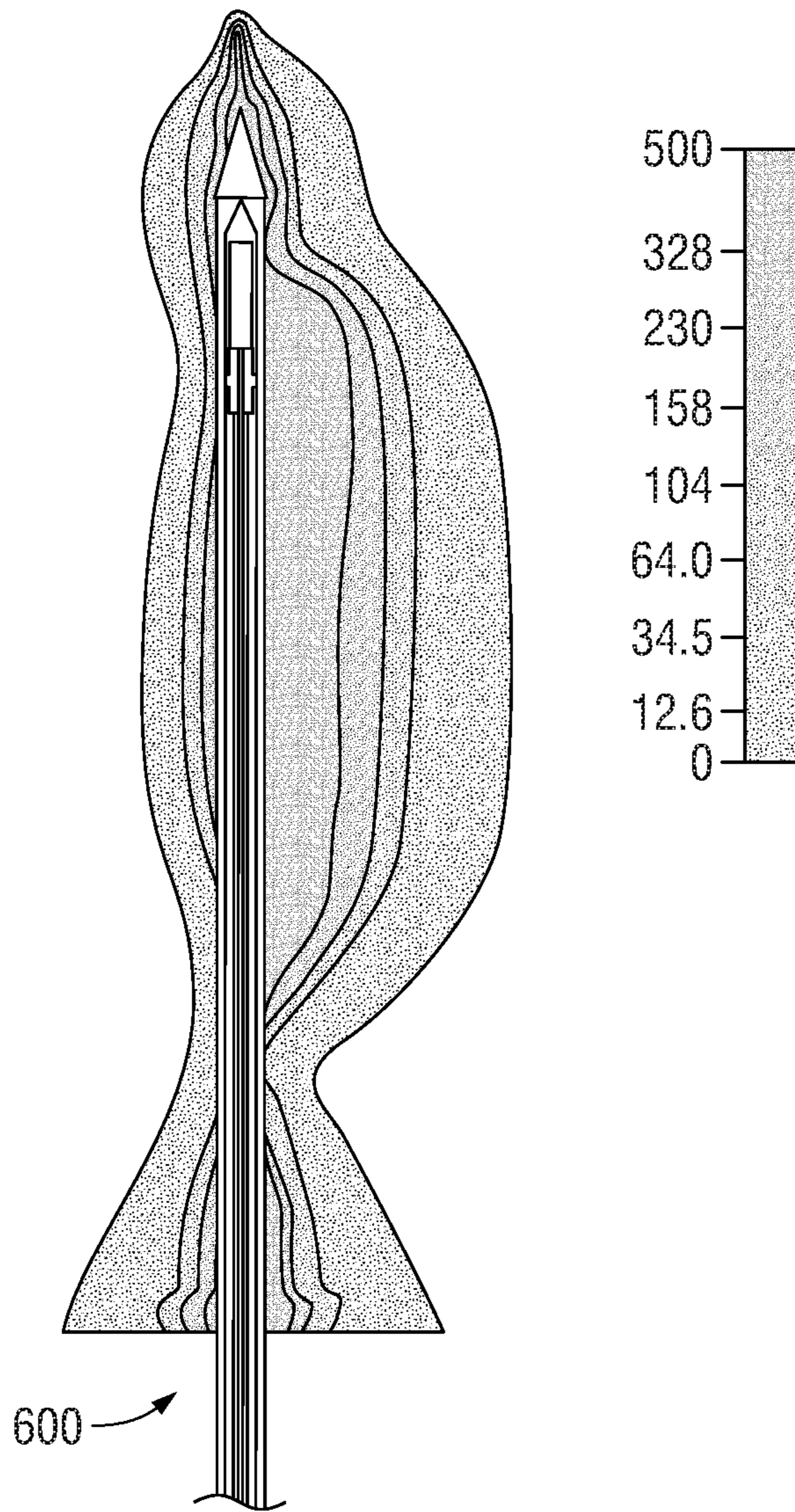


FIG. 9

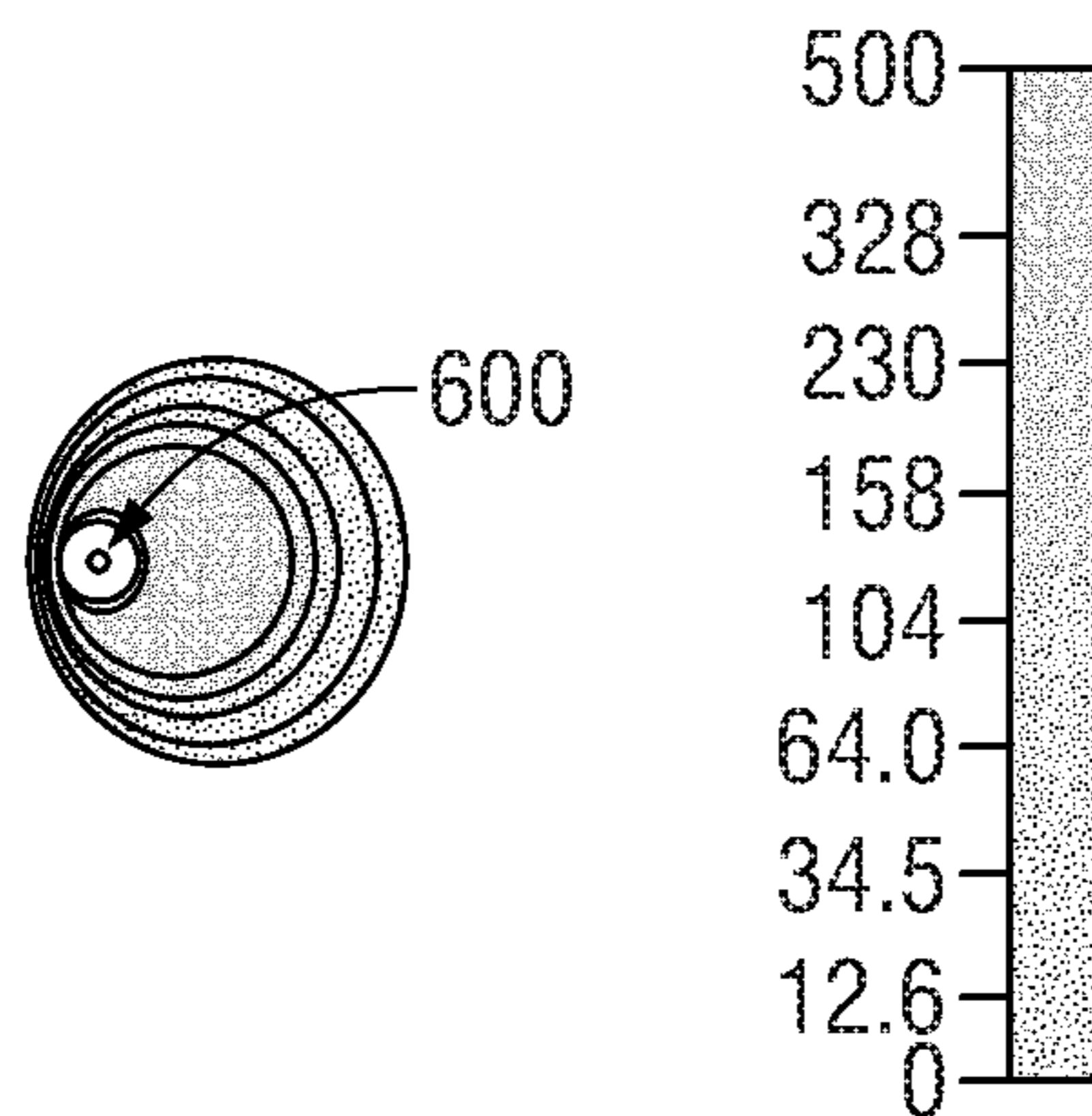


FIG. 10

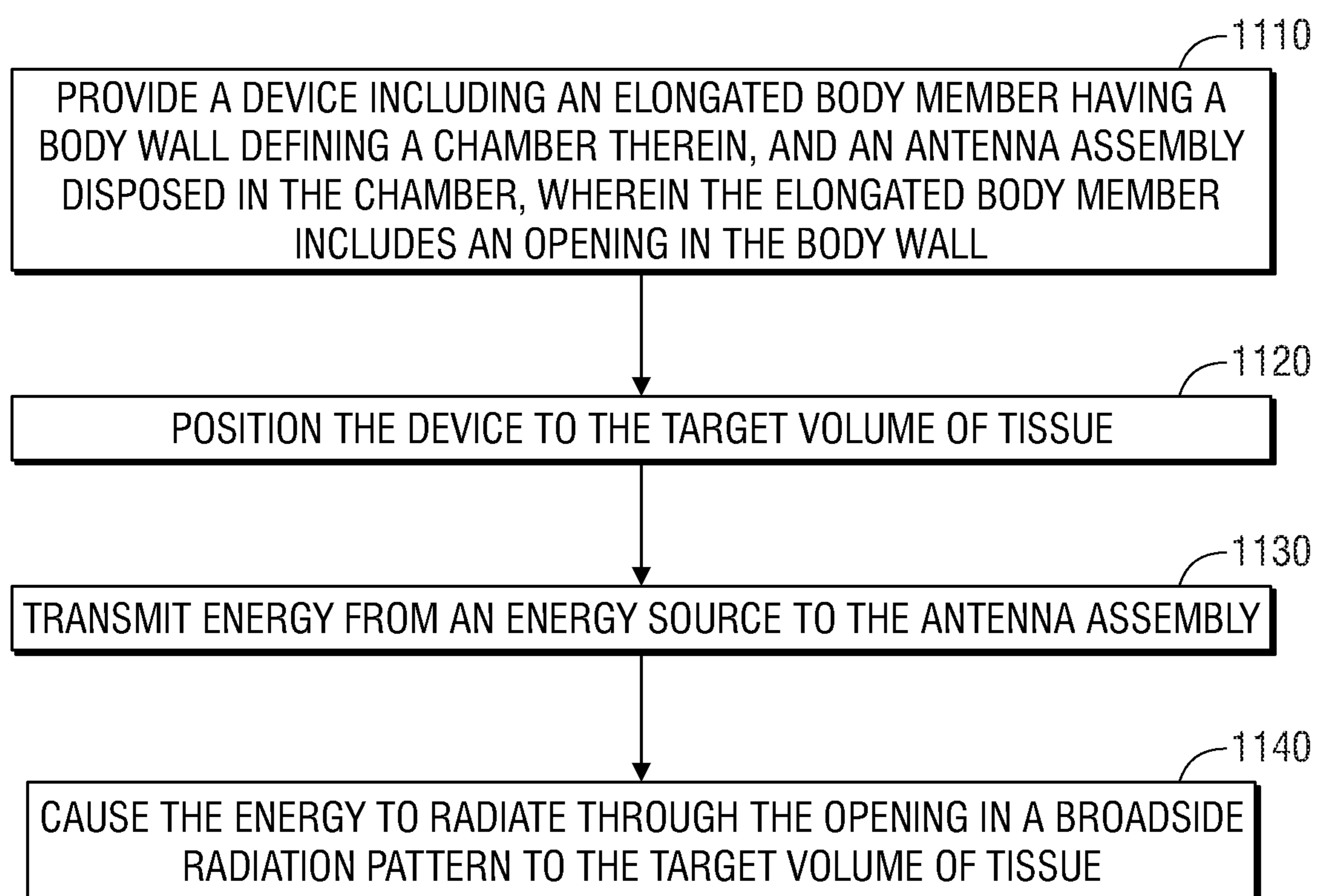


FIG. 11

ELECTROSURGICAL DEVICES WITH DIRECTIONAL RADIATION PATTERN

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a Continuation of U.S. patent application Ser. No. 14/242,048, filed on Apr. 1, 2014, which is a Divisional of U.S. patent application Ser. No. 13/567,624, filed on Aug. 6, 2012, now U.S. Pat. No. 8,690,869, which is a Continuation of U.S. patent application Ser. No. 12/476,960, filed on Jun. 2, 2009, now U.S. Pat. No. 8,235,981, the entire contents of each of which is incorporated by reference herein.

BACKGROUND

1. Technical Field

The present disclosure relates to electrosurgical devices suitable for use in tissue ablation applications and, more particularly, to electrosurgical devices with directional radiation patterns.

2. Discussion of Related Art

Treatment of certain diseases requires the destruction of malignant tissue growths, e.g., tumors. Electromagnetic radiation can be used to heat and destroy tumor cells. Treatment may involve inserting ablation probes into tissues where cancerous tumors have been identified. Once the probes are positioned, electromagnetic energy is passed through the probes into surrounding tissue.

In the treatment of diseases such as cancer, certain types of tumor cells have been found to denature at elevated temperatures that are slightly lower than temperatures normally injurious to healthy cells. Known treatment methods, such as hyperthermia therapy, heat diseased cells to temperatures above 41° C. while maintaining adjacent healthy cells below the temperature at which irreversible cell destruction may occur. These methods involve applying electromagnetic radiation to heat, ablate and/or coagulate tissue. Microwave energy is sometimes utilized to perform these methods. Other procedures utilizing electromagnetic radiation to heat tissue also include coagulation, cutting and/or ablation of tissue.

Electrosurgical devices utilizing electromagnetic radiation have been developed for a variety of uses and applications. A number of devices are available that can be used to provide high bursts of energy for short periods of time to achieve cutting and coagulative effects on various tissues. There are a number of different types of apparatus that can be used to perform ablation procedures. Typically, microwave apparatus for use in ablation procedures include a microwave generator, which functions as an energy source, and a microwave surgical instrument (e.g., microwave ablation probe) having an antenna assembly for directing the energy to the target tissue. The microwave generator and surgical instrument are typically operatively coupled by a cable assembly having a plurality of conductors for transmitting microwave energy from the generator to the instrument, and for communicating control, feedback and identification signals between the instrument and the generator.

There are several types of microwave antenna assemblies for the ablation of tissue, such as monopole, dipole and helical. In monopole and dipole antenna assemblies, microwave energy radiates perpendicularly away from the axis of

the conductor. Monopole antenna assemblies include a single elongated conductor whereas a typical dipole antenna assembly includes two elongated conductors, which are linearly aligned and positioned end-to-end relative to one another with an electrical insulator placed therebetween. Helical antenna assemblies include a helically-shaped conductor connected to a ground plane. Helical antenna assemblies can operate in a number of modes, such as normal mode (broadside), in which the field radiated by the helix is maximum in a perpendicular plane to the helix axis, and axial mode (end fire), in which maximum radiation is along the helix axis.

A microwave transmission line typically includes a long, thin inner conductor that extends along a longitudinal transmission line axis and surrounded by a dielectric material and is further surrounded by an outer conductor around the dielectric material such that the outer conductor also extends along the transmission line axis. In one variation of an antenna, a length of transmission line is provided with a plurality of openings through which energy “leaks” or radiates away from the transmission line or coaxial cable. This type of construction is typically referred to as a “leaky coaxial” or “leaky wave” antenna. A leaky wave antenna is basically a waveguiding structure constructed so as to “leak” power along the length of the guiding structure.

During certain procedures, it can be difficult to assess the extent to which the microwave energy will radiate into the surrounding tissue, making it difficult to determine the area or volume of surrounding tissue that will be ablated.

SUMMARY

The present disclosure relates to a device for directing energy to a target volume of tissue including an antenna assembly and an elongated body member. The elongated body member includes a proximal end portion and a distal end portion, wherein the proximal and distal end portions define a longitudinal axis, the elongated body member having a body wall defining a chamber therein. The antenna assembly is disposed in the chamber. The elongated body member also includes an opening in the body wall to allow energy radiated from the antenna assembly to transfer into the target volume of tissue.

The present disclosure also relates to an ablation applicator including a catheter assembly and an antenna assembly. The catheter assembly includes a tubular body member having an outer surface. The outer surface of the tubular body member includes an aperture formed therethrough. At least one of the catheter assembly and the outer surface of the tubular body member is formed of an electrically conductive material. The antenna assembly is disposed in the tubular body member of the catheter assembly. The aperture in the outer surface of the tubular body member is configured to allow energy to radiate from the antenna assembly in a directional broadside radiation pattern.

The present disclosure also relates to a method for directing energy to a target volume of tissue including the steps of providing a device including an elongated body member having a body wall defining a chamber therein, and an antenna assembly disposed in the chamber, wherein the elongated body member includes an opening in the body wall, and positioning the device to the target volume of tissue. The method also includes the steps of transmitting energy from an energy source to the antenna assembly, and

causing the energy to radiate through the opening in a broadside radiation pattern to the target volume of tissue.

BRIEF DESCRIPTION OF THE DRAWINGS

Objects and features of the presently disclosed antenna assemblies will become apparent to those of ordinary skill in the art when descriptions of various embodiments thereof are read with reference to the accompanying drawings, of which:

FIG. 1 is a schematic diagram of an ablation system according to an embodiment of the present disclosure;

FIG. 2 is a partial, longitudinal cross-sectional view of an energy applicator of the ablation system shown in FIG. 1 according to an embodiment of the present disclosure;

FIG. 3 is an enlarged view of the indicated area of detail of FIG. 2 according to an embodiment of the present disclosure;

FIG. 4 is a partial, longitudinal cross-sectional (split) view of an elongated body member configured to receive the energy applicator of FIG. 2 according to an embodiment of the present disclosure;

FIG. 5 is a partial, perspective view of an electrosurgical device including the elongated body member of FIG. 4 shown with the energy applicator of FIG. 2 (in phantom lines) disposed therein according to an embodiment of the present disclosure;

FIG. 6 is partial, longitudinal cross-sectional view of the electrosurgical device of FIG. 5 according to an embodiment of the present disclosure;

FIG. 7 is a schematic diagram of an ablation system including the electrosurgical device of FIGS. 5 and 6 according to an embodiment of the present disclosure;

FIG. 8 is a schematic diagram of the electrosurgical device of FIGS. 5 through 7 shown with indicia graduation marks and an indicia alignment mark according to an embodiment of the present disclosure;

FIGS. 9 and 10 are schematically-illustrated representations of simulation results showing broadside radiation patterns according to embodiments of the present disclosure; and

FIG. 11 is a flowchart illustrating a method of directing energy to a target volume of tissue according to an embodiment of the present disclosure.

DETAILED DESCRIPTION

Hereinafter, embodiments of the presently disclosed electrosurgical device with a directional radiation pattern will be described with reference to the accompanying drawings. Like reference numerals may refer to similar or identical elements throughout the description of the figures. As shown in the drawings and as used in this description, and as is traditional when referring to relative positioning on an object, the term “proximal” refers to that portion of the apparatus that is closer to the user and the term “distal” refers to that portion of the apparatus that is further from the user.

Electromagnetic energy is generally classified by increasing energy or decreasing wavelength into radio waves, microwaves, infrared, visible light, ultraviolet, X-rays and gamma-rays. As it is used in this description, “microwave” generally refers to electromagnetic waves in the frequency range of 300 megahertz (MHz) (3×10^8 cycles/second) to 300 gigahertz (GHz) (3×10^{11} cycles/second). As it is used in this description, “ablation procedure” generally refers to any ablation procedure, such as microwave ablation or micro-

wave ablation assisted resection. As it is used in this description, “transmission line” generally refers to any transmission medium that can be used for the propagation of signals from one point to another.

Various embodiments of the present disclosure provide electrosurgical devices for treating tissue and methods of directing electromagnetic radiation to a target volume of tissue. Embodiments may be implemented using electromagnetic radiation at microwave frequencies or at other frequencies. An electrosurgical system including an energy applicator, according to various embodiments, is designed and configured to operate between about 500 MHz and about 10 GHz with a directional radiation pattern.

Various embodiments of the presently disclosed electrosurgical device with a directional radiation pattern are suitable for microwave ablation and for use to pre-coagulate tissue for microwave ablation assisted surgical resection. Although various methods described hereinbelow are targeted toward microwave ablation and the complete destruction of target tissue, it is to be understood that methods for directing electromagnetic radiation may be used with other therapies in which the target tissue is partially destroyed or damaged, such as, for example, to prevent the conduction of electrical impulses within heart tissue. In addition, although the following description describes the use of a dipole microwave antenna, the teachings of the present disclosure may also apply to a monopole, helical, or other suitable type of microwave antenna.

FIG. 1 shows an electrosurgical system 10, according to an embodiment of the present disclosure, which includes an energy applicator or probe 100. Energy applicator 100 includes an antenna assembly 12 that is connected by a feedline 110 (or shaft) via a transmission line 15 to a connector 16, which may further operably connect the probe 100 to a power generating source 28, e.g., a microwave or radio frequency (RF) electrosurgical generator. In some embodiments, the power generating source 28 is configured to provide microwave energy at an operational frequency from about 500 MHz to about 2500 MHz. In other embodiments, the power generating source 28 is configured to provide microwave energy at an operational frequency from about 500 MHz to about 10 GHz. Power generating source 28 may be configured to provide various frequencies of electromagnetic energy. Transmission line 15 may additionally or alternatively provide a conduit (not shown) configured to provide coolant from a coolant source 18 to the probe 100.

Located at the distal end of the antenna assembly 12 is an end cap or tapered region 120, which may terminate in a sharp tip 123 to allow for insertion into tissue with minimal resistance. One example of a straight probe with a sharp tip that may be suitable for use as the energy applicator 100 is commercially available under the trademark Evident™ offered by Covidien. The end cap portion or tapered region 120 may include other shapes, such as, for example, a tip 123 that is rounded, flat, square, hexagonal, or cylindroconical.

In some variations, the antenna assembly 12 includes a distal radiating portion 105 and a proximal radiating portion 140. A feedpoint or puck 130 may be provided. In some embodiments, the puck 130, having length “L2”, is a junction member that couples the proximal radiating portion 140 and the distal radiating portion 105. Puck 130, or portions thereof, may be disposed between the proximal and distal radiating portions, 140 and 105. Puck 130 may be formed from any suitable elastomeric or ceramic dielectric material by any suitable process. In some embodiments, the puck 130

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is formed by overmolding and includes a thermoplastic elastomer, such as, for example, polyether block amide (e.g., PEBAX®, manufactured by The Arkema Group of Colombes, France), polyetherimide (e.g., ULTEM® and/or EXTEM®, manufactured by SABIC Innovative Plastics of Saudi Arabia) and/or polyimide-based polymer (e.g., VESPEL®, manufactured by E. I. du Pont de Nemours and Company of Wilmington, Del., United States). Puck **130** may be formed using any suitable overmolding compound by any suitable process, and may include use of a ceramic substrate.

In some embodiments, the antenna assembly **12** may be provided with a coolant chamber (not shown). Additionally, the puck **130** may include coolant inflow and outflow ports (not shown) to facilitate the flow of coolant into, and out of, the coolant chamber. Examples of coolant chamber and coolant inflow and outflow port embodiments are disclosed in commonly assigned U.S. patent application Ser. No. 12/401,268 filed on Mar. 10, 2009, entitled “COOLED DIELECTRICALLY BUFFERED MICROWAVE DIPOLE ANTENNA”, and U.S. Pat. No. 7,311,703, entitled “DEVICES AND METHODS FOR COOLING MICROWAVE ANTENNAS”.

In some embodiments, the antenna assembly **12** may be provided with an outer jacket (not shown) disposed about the distal radiating portion **105**, the puck **130** and/or the proximal radiating portion **140**. The outer jacket may be formed of any suitable material, such as, for example, polymeric or ceramic materials. The outer jacket may be applied by any suitable method, such as, for example, heat shrinking, overmolding, coating, spraying dipping, powder coating, baking and/or film deposition.

During microwave ablation, e.g., using the electrosurgical system **10**, the probe **100** is inserted into or placed adjacent to tissue and microwave energy is supplied thereto. Ultrasound or computed tomography (CT) guidance may be used to accurately guide the probe **100** into the area of tissue to be treated. Probe **100** may be placed percutaneously or surgically, e.g., using conventional surgical techniques by surgical staff. A clinician may pre-determine the length of time that microwave energy is to be applied. Application duration may depend on many factors such as tumor size and location and whether the tumor was a secondary or primary cancer. The duration of microwave energy application using the probe **100** may depend on the progress of the heat distribution within the tissue area that is to be destroyed and/or the surrounding tissue. Single or multiple probes **100** may provide ablations in short procedure times, e.g., a few minutes, to destroy cancerous cells in the target tissue region.

A plurality of probes **100** may be placed in variously arranged configurations to substantially simultaneously ablate a target tissue region, making faster procedures possible. Multiple probes **100** can be used to synergistically create a large ablation or to ablate separate sites simultaneously. Tissue ablation size and geometry is influenced by a variety of factors, such as the energy applicator design, number of energy applicators used simultaneously, time and wattage.

Referring to FIGS. **2** and **3**, an embodiment of the antenna assembly **12** of FIG. **1** is shown and includes an inner conductor **210**, having length “**L3**”, an outer conductor **260**, having length “**L1**”, and may include a first dielectric material **240** separating the inner conductor **210** and the outer conductor **260**. In some embodiments, the inner conductor **210** is formed from a first electrically conductive material (e.g., stainless steel) and the outer conductor **260** is

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formed from a second electrically conductive material (e.g., copper). In some embodiments, the outer conductor **260** coaxially surrounds the inner conductor **210** along a distal portion of the antenna assembly **12**, having length “**L1**”, as shown in FIG. **2**. Inner conductor **210** and the outer conductor **260** may be formed from any suitable electrically conductive material.

First dielectric material **240** may be formed from any suitable dielectric material, including, but not limited to, ceramics, water, mica, polyethylene, polyethylene terephthalate, polyimide, polytetrafluoroethylene (PTFE) (e.g., Teflon®, manufactured by E. I. du Pont de Nemours and Company of Wilmington, Del., United States), glass, or metal oxides. Antenna assembly **12** may be provided with a second dielectric material **290** surrounding the outer conductor **260** and/or the puck **130**, or portions thereof. Second dielectric material **290** may be formed from any suitable dielectric material. In some embodiments, the second dielectric material **290** is formed from a material with a dielectric constant different than the dielectric constant of the first dielectric material **240**.

In some embodiments, the antenna assembly **12**, having length “**L4**”, includes a conductor end portion **280**, which may be formed from any suitable electrically conductive material. In some embodiments, the conductor end portion **280** is coupled to the inner conductor **210** and may be formed of the same material as the inner conductor **210**. As shown in FIG. **2**, the conductor end portion **280** may be spaced apart a length “**L2**” from the outer conductor **260** by the puck **130**, having length “**L2**”, disposed therebetween. Tapered region **120**, or portions thereof, may surround a proximal portion of the conductor end portion **280**. In some embodiments, the conductor end portion **280** is substantially cylindrically shaped, and may be formed from stainless steel. The shape and size of the conductor end portion **280** may be varied from the configuration depicted in FIG. **2**. In some embodiments, at least a portion of the conductor end portion **280** is surrounded by the second dielectric material **290**.

FIG. **4** shows an elongated body member **400**, according to an embodiment of the present disclosure, which is configured to receive an energy applicator (e.g., **100** shown in FIG. **1**), or portions thereof. An electrosurgical device that includes the elongated body member **400** is shown in FIGS. **5** and **6**. In some embodiments, the elongated body member **400** is substantially tubular, except for a tapered portion **420** tapering from the distal end thereof. Tapered portion **420** may include a tip portion, which may be advantageously configured to facilitate penetration of tissue. Although the surfaces of the tapered portion **420** shown in FIGS. **4** through **6** are generally flat, the surfaces of the tapered portion **420** according to various embodiments may be curved or may include a combination of flat, sloped or curved portions. The shape and size of the tapered portion **420** may be varied from the configuration depicted in FIGS. **4** through **6**.

Elongated body member **400** includes a proximal end portion, a distal end portion, wherein the proximal and distal end portions define a longitudinal axis “**A-A**”, a chamber **480** surrounding and extending along the axis “**A-A**”, and a body wall **450** surrounding the chamber **480**. Chamber **480** is configured to receive at least a portion of an energy applicator (e.g., **100** shown in FIG. **1**). In some embodiments, the chamber **480** is dimensioned and configured to receive an antenna assembly (e.g., **12** shown in FIGS. **5** and

6) within the chamber 480. The shape and size of the chamber 480 may be varied from the configuration depicted in FIGS. 5 and 6.

Body wall 450 is provided with at least one opening 440 therethrough to allow electromagnetic energy radiated from the energy applicator to transfer into the target volume of tissue (e.g., "T" shown in FIG. 7). In some embodiments, the opening 440 is configured for radiating energy in a broadside radiation pattern, such as the non-limiting example directional radiation patterns shown in FIGS. 9 and 10. As shown in FIGS. 4 and 5, a substantially slot-shaped opening 440, having length "L5" and width "W", may be positioned at a side portion of the body wall 450, and may have a longitudinal axis that extends substantially parallel to the axis "A-A". The shape and size of the opening 440 may be varied from the configuration depicted in FIGS. 4 and 5.

Elongated body member 400 may include a plurality of openings 440. In some embodiments, the body wall 450 is provided with a plurality of elongated slots, which may be spaced longitudinally along the elongated body member 400. The size, shape and/or location of each opening 440 may be based on the wavelength of the radiated energy along the antenna radiating portion (e.g., 140 and/or 105 shown in FIG. 2). The number of openings 440 may be based on various factors, such as, for example, the volume of target tissue to be treated, the desired procedure, the wavelength of the electromagnetic energy to be radiated, and the shape and/or dimensions of the openings. The size and/or shape of each opening 440 may be based on the location of the opening 440 relative to a distal tip of the antenna assembly 12. In some embodiments, the antenna assembly 12 is a dipole antenna, and the openings 440 may be configured to encompass any radial angle, length, and positioning with respect to the antenna dipole arms.

Opening 440 may be provided with an electrically non-conductive material 442. Nonconductive material 442 may include a nonconductive RF transparent material, e.g., a glass fiber epoxy composite or polyimide. In some embodiments, the nonconductive material 442 substantially entirely fills the recess or void formed by the opening 440 in the elongated body member 400. Opening 440 may be filled with the nonconductive material 442 such that the external surface of the elongated body member 400 is substantially smooth.

Elongated body member 400 may include an outer jacket (e.g., 458 shown in FIG. 4 or 558 shown in FIGS. 5 and 6). Outer jacket 458 may be formed of any suitable electrically conductive material, such as, for example, electrically conducting metallic ceramic and polymeric electrically conductive materials. Outer jacket 458 may include metal and/or conductive oxide layers. Outer jacket 458 may be configured to surround the body wall 450, or portions thereof, and/or the tapered portion 420, or portions thereof. In some embodiments, the outer jacket 458 is formed of an electrically conductive material and configured to substantially surround the body wall 450, except for the opening 440 and the electrically nonconductive material 442 disposed therein.

Elongated body member 400 may be a tubular body (e.g., a tubular body member of a catheter assembly) having an outer surface (e.g., 458 shown in FIGS. 5 and 6) that includes a single or multiple openings 440 formed therethrough. In some embodiments, the tubular body member is formed of an electrically conductive material and/or the outer surface of the tubular body member is formed of an electrically conductive material.

FIGS. 5 through 7 show an electrosurgical device 500, according to an embodiment of the present disclosure, which

is configured to operate with a directional radiation pattern. Electrosurgical device 500 includes the elongated body member 400 of FIG. 4 and the antenna assembly 12 of FIG. 2 disposed within the chamber 480 of the elongated body member 400. Antenna assembly 12 and the elongated body member 400 may be disengageably coupled to each other. Electrosurgical device 500 may be sufficiently small in diameter to be minimally invasive of the body, which may reduce the preparation time of the patient as might be required for more invasive penetration of the body.

Electrosurgical device 500 may include a moveable sleeve member 470 (FIG. 4) associated with elongated body member 400 and coaxially aligned with the axis "A-A". Such a sleeve member 470 may either be on the outside or the inside of elongated body member. In some embodiments, the sleeve member 470 may be adapted to be rotationally moveable and/or slideably moveable along the outside of the antenna assembly 12 to various axial positions or various rotational positions to vary the size of the opening 440 with rotation angle. The sleeve member 470 may include a plurality of apertures and may be moveable relative to the elongated body member 400 to various positions, thereby providing variably dimensioned electromagnetic "windows" within the opening 440. In other embodiments, the elongated body member 400 itself may be adapted to be rotationally moveable and/or slideably moveable along the outside of the antenna assembly 12.

FIG. 7 shows an electrosurgical system 700, according to an embodiment of the present disclosure, which includes the electrosurgical device 500 of FIGS. 5 and 6. Electrosurgical device 500 is coupled to a connector 16 via a transmission line 15, which may further connect the electrosurgical device 500 to a power generating source 28, e.g., a microwave or RF electrosurgical generator. During a procedure, e.g., an ablation, the electrosurgical device 500 of the electrosurgical system 700 is inserted into or placed adjacent to tissue "T" and energy is supplied thereto. Electrosurgical device 500 may be placed percutaneously or surgically. Ultrasound or computed tomography (CT) guidance may be used to accurately guide the electrosurgical device 500 into the area of tissue "T" to be treated.

FIG. 8 shows an electrosurgical device 800, which is similar to the electrosurgical device 500 of FIGS. 5 through 7, except for the indicia alignment mark 810 and the indicia graduation marks 880 on the proximal end of the electrosurgical device 800. Indicia alignment mark 810 and/or the indicia graduation marks 880 may be carried on or inscribed into the elongated body member of the electrosurgical device 800. In some embodiments, the electrosurgical device 800 includes a plurality of indicia graduation marks 880 defining units of linear measure, which may be inscribed substantially circumferentially about the elongated body member. Indicia graduation marks 880 may be used to indicate the relative position of the opening 440 with respect to the surface of the tissue "T". In some embodiments, the indicia graduation marks 880 are used to indicate the position of the distal end of the opening 440 relative to the surface of the tissue "T". Indicia graduation marks 880 may be arranged to form an incremental pattern using any standard measure of length, e.g., inches or centimeters.

In some embodiments, the electrosurgical device 800 includes an indicia alignment mark 810, e.g., a colored stripe, which is readily visible along the proximal end of the elongated body member. Indicia alignment mark 810 is positioned on the elongated body member such that the longitudinal axis of the alignment mark 810 substantially aligns with the longitudinal axis of the opening 440, to

provide a visual cue to the surgeon to allow orientation of the direction of flow of the energy to coincide with the indicia alignment mark **810**. As shown in FIG. **8**, one or more of the indicia graduation marks **880** may overlap the indicia alignment mark **810**. The shape and size of the indicia alignment mark **810** and the indicia graduation marks **880** may be varied from the configurations depicted in FIG. **8**.

FIGS. **9** and **10** are schematically-illustrated representations of simulation results showing directional radiation patterns. The illustrated results are based on a simulation that modeled operation of an electrosurgical device **600**, which is configured to operate with a directional radiation pattern. Electrosurgical device **600** shown in FIGS. **9** and **10** is similar to the electrosurgical device **500** of FIGS. **5** through **7** and further description thereof is omitted in the interests of brevity.

FIG. **11** is a flowchart illustrating a method of directing energy to a target volume of tissue, according to an embodiment of the present disclosure. In step **1110**, an electrosurgical device (e.g., **500** shown in FIGS. **5** through **7**) is provided, wherein the device includes an elongated body member (e.g., **400** shown in FIG. **4**) having a body wall defining a chamber therein, and an antenna assembly disposed in the chamber, wherein the elongated body member includes an opening (e.g., **440** shown in FIG. **7**) in the body wall.

In step **1120**, the device is positioned to the target volume of tissue. The electrosurgical device may be inserted directly into tissue (e.g., "T" shown in FIG. **7**), inserted through a lumen, e.g., a vein, needle or catheter, placed into the body during surgery by a clinician, or positioned in the body by other suitable methods known in the art. The electrosurgical device is configured to operate with a directional radiation pattern. In some embodiments, the electrosurgical device is configured to operate with a broadside radiation pattern. In other embodiments, the catheter or needle contains the opening to allow a directional radiation pattern.

In step **1130**, energy from an energy source (e.g., **28** shown in FIG. **7**) is transmitted to the antenna assembly. For example, the energy source may be any suitable electrosurgical generator for generating an output signal. In some embodiments, the energy source is a microwave energy source, and may be configured to provide microwave energy at an operational frequency from about 500 MHz to about 10 GHz.

In step **1140**, the energy from the energy source is caused to radiate through the opening in the elongated body member. In some embodiments, the opening is configured for radiating energy in a broadside radiation pattern.

The above-described electrosurgical devices for treating tissue and methods of directing electromagnetic radiation to a target volume of tissue may be used to provide directional microwave ablation, wherein the heating zone may be focused to one side of the electrosurgical device, thereby allowing clinicians to target small and/or hard tumors without having to penetrate the tumor directly or kill more healthy tissue than necessary. The presently disclosed electrosurgical devices may allow clinicians to avoid ablating critical structures, such as large vessels, healthy organs or vital membrane barriers, by placing the electrosurgical device between the tumor and critical structure and directing the electromagnetic radiation toward the tumor and away from the critical structure.

Although embodiments have been described in detail with reference to the accompanying drawings for the purpose of illustration and description, it is to be understood that the inventive processes and apparatus are not to be construed as limited thereby. It will be apparent to those of ordinary skill in the art that various modifications to the foregoing embodiments may be made without departing from the scope of the disclosure. For example, with reference to FIGS. **4** and **5**, the electrosurgical device **500** may be rotatable about axis "A-A" such that the directional radiation pattern rotates therewith.

What is claimed is:

1. An electrosurgical device for treating tissue, the electrosurgical device comprising:

an elongated body member defining a chamber therein and having a body wall, the body wall having an opening defined therethrough, the elongated body member including an electrically conductive outer jacket disposed on the body wall;

an antenna assembly disposed in the chamber and configured to deliver electrosurgical energy to tissue; and an outer sleeve disposed about the elongated body member, at least one of the elongated body member or the outer sleeve movable relative to the other to control exposure of the opening of the body wall.

2. The electrosurgical device of claim **1**, wherein the outer sleeve is longitudinally slidable along a longitudinal axis defined by the elongated body member.

3. The electrosurgical device of claim **1**, wherein the outer sleeve is rotatable about a longitudinal axis defined by the elongated body member.

4. The electrosurgical device of claim **1**, wherein the outer sleeve is configured to control an amount of the electrosurgical energy delivered from the antenna assembly to the tissue.

5. The electrosurgical device of claim **1**, wherein the antenna assembly and the elongated body member are releasably coupled to each other.

6. The electrosurgical device of claim **1**, further comprising a filling of electrically nonconductive material disposed within the opening.

7. The electrosurgical device of claim **1**, wherein the elongated body member includes a tapered distal tip configured to penetrate tissue.

8. The electrosurgical device of claim **1**, wherein the outer sleeve includes a plurality of apertures defined through a surface of the outer sleeve.

9. An electrosurgical device for treating tissue, the electrosurgical device comprising:

an elongated body member including an electrically conductive outer jacket;

an antenna assembly disposed within the elongated body member and configured to deliver electrosurgical energy to tissue; and

an outer sleeve disposed about the elongated body member, at least one of the elongated body member or the outer sleeve movable relative to the other to control exposure of an opening in the elongated body member.

10. The electrosurgical device according to claim **9**, wherein the elongated body member defines a chamber extending along a longitudinal axis defined by the elongated body member, at least a portion of the antenna assembly disposed within the chamber.